The Impact of Sorting Fish Prior to Processing — A Pilot Project

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THE IMPACT OF SORTING FISH PRIOR TO PROCESSING - A PILOT PROJECT

By

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ABSTRACT

The NewLantic Group. August 1987. The Impact of Sorting Fish Prior to Processing - a Pilot Project. Can. Ind. Rep. Fish. Aquat. Sci. 182: vii + 57 p.

Between February and April of 1986 the NewLantic Group conducted experiments with a fish sorting machine for implementation in Newfoundland fish processing plants to determine the benefits from both a production and an economic perspective. The mechanical sorting of fish was tested with a modified Model 481 Scangrader sorting machine at the Fishery Products International Ltd. plant in Trepassey, Newfoundland. This report includes the observations of the consultant with respect to fish sorting in a production environment and the difficulties associated with the project.

RÉSUMÉ

The NewLantic Group. August 1987. The Impact of Sorting Fish Prior to Processing - a Pilot Project. Can. Ind. Rep. Fish. Aquat. Sci. 182: vii + 57 p.

Entre février et avril 1986, le Groupe Newlantic a mené des expériences avec une machine à trier le poisson en vue de l'implanter dans les usines de transformation de Terre-Neuve afin de déterminer les avantages sur le plan de la production et sur le plan économique. Le tri mécanique du poisson a été testé en utilisant un appareil de tri modifié Scangrader, modèle 481 à l'usine de la Fishery Products International Ltd. située à Trepassey (Terre-Neuve). Le présent rapport comprend les observations de l'expert-conseil en ce qui concerne le tri du poisson en milieu de production et les difficultés qui sont rattachées au projet.

PREFACE

Innovations to fish processing operations are continuously being introduced in pursuit of increased economic returns. The Fisheries Development Division of the Department of Fisheries and Oceans encourages the industry to identify and incorporate processing technology which can improve the performance of the fish processing plants. A contract was awarded to The NewLantic Group, a consulting firm, to plan and conduct commercial tests of the impact of segregation of raw material in Newfoundland fish plants.

The opinions and interpretations expressed in the report are those of the author, and do not necessarily reflect those of the Department of Fisheries and Oceans.

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INTRODUCTION

Yields from groundfish at Newfoundland fish plants are lower than they might be. Part of this problem is caused by inconsistency in yield performance both between production workers and by a single worker at different times. Some workers are able to equal or exceed yields obtained from machine filleting, but they may not do so consistently. Other workers cannot obtain yields as high as those from properly maintained and adjusted machines. Hand filleters are more likely than machines to cause raggedness in fillets, because of a tearing action commonly used in the process of removing a fillet from a fish. Production costs are generally lower when filleting machines are used.

In Newfoundland, filleting machines have not been widely accepted. During 1985, Nord Limited, the principal supplier of such machines to the local market, estimated that there was a total of approximately 50 filleting machines in use in about 200 processing plants. Most of the machines in use were not considered to be up to the current state of the art.

One of the reasons that mechanical filleting has not been adopted to a greater extent in Newfoundland is the great variability in raw materials processed. A single plant must usually process a range of different fish species, each of which would require filleting machines with design features appropriate for the particular species. Filleting all of the different species mechanically would require a large investment in equipment and plant facilities, much of which likely would not be well

utilized. In addition, the fish of any one species usually include a range of sizes and quality characteristics, which affect the performance of machines, since they generally perform best in processing consistent raw materials. Because of limited availability of investment capital and the variability in their raw materials, most companies processing Atlantic groundfish in Newfoundland have continued to depend on the flexibility inherent in human beings to adapt processing activities to different requirements, and have not adopted machines for filleting.

During the period from 1980 - 1985, companies processing groundfish in Atlantic Canada experienced severe financial difficulties, for a variety of reasons. A program to extricate the industry from these difficulties must include:

- Increasing earnings by obtaining higher yields and offering to the marketplace an improved mix of products.
- Lowering costs by increasing production efficiency.

If product yeilds are to be increased and production costs lowered through improvements in production efficiency, processing companies are likely to have to make greater use of technologies which can help to enhance profitability. Because of the variability in production requirements, this means either that machines must be made more flexible or that production systems must be redesigned to reduce the degree of flexibility required at any one processing step.

Fish are highly variable raw materials for processing. Different species have quite different characteristics and fish of the same species can be very different in size. Biological cycles affect their intrinsic

quality characteristics, such as water content and odour, so that fish of the same species, even fresh out of the water, can vary in quality at different times. Variable harvesting efforts provide quantities for processing that fluctuate dramatically during the different seasons. Differing harvesting practices provide fish not only of different species but fish of the same species with differing size and quality characteristics. Fish are fragile and highly perishable, so further variability in quality can be caused by methods used for handling and storing catches and transporting them to plants for processing.

These variable raw materials are used to produce a wide range of end product packs to satisfy different needs in the marketplace. The challenge to people in production is to maximize the yield of output products from their raw materials and to obtain the mix of products which gets the best value from them. In response to changing demands in the marketplace, Newfoundland companies processing Atlantic groundfish have put more emphasis on production of fillet packs in recent years, reducing the proportion of block products in their output mix.

In general, the need to maintain the intrinsic fish quality characteristics of texture, colour, and odour/flavour is higher in producing fillet packs than in the production of blocks; however, different fillet packs may have different requirements for these aspects of quality. Consequently, more effort has had to be put into preserving these characteristics and to sorting fish into products with different requirements for them.

Block products are regular in shape and allow relatively good control over the size of serving portions, a particularly important need of the food service industry and of companies involved in secondary processing of blocks into products for the retail market. In contrast, fillets are irregular in shape, making portion control more difficult and requiring processing companies to sort fillets by size or section them into consistently sized pieces.

To obtain the best value from their raw materials, production personnel must perform a number of tasks, including the following:

1. Sort fillets on the basis of their intrinsic quality characteristics for allocation to products with corresponding specifications.
2. Sort fillets which go into some packs by size.
3. Section (cut) some fillets into portions which have consistent size and quality characteristics.

Sorting fish by size and quality, and sectioning fillets into consistently sized portions, have become much more important work activities in recent years than they were in the past.

Because of the judgment required to assess fish with variable characteristics, all trimming of fillets is done by people rather than machines. In some plants, trimming and grading are performed by different people. However, as changes have taken place in the kinds of products in demand in the marketplace, most of the extra work required to produce larger ranges of output products has been assigned to the trimming function at many plants, adding considerably to its complexity.

At one time, trimming consisted primarily of removing defects and pin-bones from fillets. In recent years it has increasingly come to include:

- Removing nape material, if required.
- Sectioning fillets, if required.
- Sorting fillets or portions by quality.
- Sorting fillets or portions by size.

Because of this, trimming is now by far the most complex work function and the one in which workers' performance is most critical in determining the mix - and therefore the value - of output products obtained from the raw materials processed. This complexity can be reduced somewhat for production of Individually Quick Frozen (I.Q.F.) products, because in some plants these are sorted mechanically by weight, after the freezing process. However, fillets destined for other products are usually sorted on the basis of visual inspection by workers if they have to be segregated by size.

Accordingly, inconsistency in Canadian fish products made from Atlantic groundfish can be traced to:

1. Inconsistency inherent in the raw materials processed.
2. Increased complexity in the mix of output products.
3. Methods used to turn variable raw materials into output products.

In northern Europe, virtually all filleting is done by machines and great care is taken to maintain and adjust the machines to obtain optimum yields. Materials handling is more automated, something which has been made possible largely by the relatively limited variability in raw materials and ranges of output products.

Although some work has been done in northern Europe to develop technology for sorting fish according to quality characteristics, such technology is in the research and development stage. Sorting by quality prior to processing is still being done, somewhat subjectively, by people who inspect the fish, usually on the basis of their external mechanical or electronic machines to sort their raw materials by size prior to processing.

Benefits from work simplification due to processing fish sorted by size would likely be considerably less in northern Europe than in Newfoundland, because plants there customarily require a much more limited range of output products from their workers at any one time. Consequently, the principal benefits expected from sorting appear to be those deriving from optimizing the performance of processing equipment. Sorting allows the Europeans to control the range fo sizes going to their filleting machines, and thereby to limit the degree of variability which must be accommodated at each succeeding step in the process.

MATERIALS AND METHODS

Sorting of fish prior to processing seems to offer opportunities to processing companies for one or more of the following:

1. Allowing greater use of profit enhancing technologies - particularly filleting machines - by limiting the variability in raw materials being processed at any given time to that consistent with the capabilities of the technologies, as determined by their design characteristics.

2. Optimizing output yields through limiting the degree of variability in raw materials which must be accommodated at any one time.
3. Decreasing the complexity of grading decisions which must be made by production workers, and therefore the rate at which errors are made, thereby increasing product consistency.
4. Improving customization of fish products for particular customers' needs.

It was felt that these potential benefits may be significant for improving the profitability of operations for companies processing Atlantic groundfish in Newfoundland.

Proposals were requested by Fisheries Development Division, D.F.O., Newfoundland Region to plan and conduct commercial tests on the impact of segregation of raw material in Newfoundland fish processing plants. The objectives stated for the work were:

1. To identify the optimum system for sorting raw material by size and by quality at Newfoundland fish processing plants.
2. To quantify the net economic benefits to fish processing plants of sorting raw material.

In effect, the work program comprised the evaluation of the technical and economic feasibility of sorting raw materials prior to processing and, if sorting was considered feasible, the determination of how it could be best incorporated into a production system.

Sorting in accordance with quality factors must be considered in the overall design of a production system. However, because equipment for sorting fish on the basis of **quality** is now only in the development stage

and has not been applied on a commercial basis, the project focused mainly on the use of technology for sorting fish by **size.**

Technology for sorting fish by size is reasonably well developed and in use in fish plants in northern Europe. Yet, there are significant differences between fish processing in northern Europe and in Newfoundland. Accordingly, the main emphasis of this study was on determining how the concept of sorting could be applied in the context of the Newfoundland fishing industry.

Groundfish of the order gadiformes (for example, cod) and order pleuronectiformes (flatfish) make up most of the raw materials processed in Newfoundland fish plants. These species present the most difficult sorting problems, because of the diversity of both their physical characteristics and their many end products. At most plants all of these varieties of fish are customarily processed using the same equipment. For this reason, and because these are the most important fish species processed in Newfoundland, investigation of the impact of raw material sorting was limited to consideration of production systems designed for them only.

In preparing our proposal to carry out the project, the Newlantic Group made arrangements with Scanvaegt Knud Grundtvig A/S, a leading supplier of weighing and sorting equipment to fish processing companies in northern Europe, for the use of an electronic size grading machine suitable for sizing fish of both gadoid and flatfish species. Because of the time of year during which the project was to be carried out, only plants supplied by offshore trawlers would have sufficient raw materials to allow adequate testing to be done. Accordingly, arrangements were made with

Fishery Products International Limited (FPI) to carry out the experiments in its plant at Trepassey, Newfoundland.

PROJECT MANAGEMENT

The NewLantic Group worked with the suppliers of the sorting machine to specify the features required, the time it would be available, and the prepatory work needed prior to installation. To some extent, this involved defining how experiments would be conducted, the types of information that would be collected, and the procedures that would be used for analyzing the information. Discussions were also held with personnel from FPI to determine a suitable location for the machine and to arrange for availability of power, air, and ancillary equipment needed to allow the machine to be used.

On arrival the machine underwent certain modifications for preparation for installation in a fish plant:

- A hopper/incline conveyor owned by FPI was refurbished to make it suitable for feeding raw materials to the machine.
- A chute to direct the flow of raw materials from the incline conveyor and a stand for the machine operator were fabricated.
- Chutes pre-fabricated in the United States for directing sorted fish into containers were attached to the machine.

These components were tested prior to transporting the equipment to Trepassey for installation. Following installation a technician from Baader North American Inc., the supplier's representative, adjusted the machine for use and explained procedures for operating it. The technician

remained at the plant during a trial period to ensure that the machine was operating properly.

Before beginning work, the NewLantic Group reviewed the overall structure of the experiments to be carried out with personnel from both FPI and DFO. Experimental procedures were reviewed in some detail with management personnel at the Trepassey plant. People who were to be involved in the experiments received special training. Special forms were designed to collect data from the project and a computer model was developed for analyzing the data. As results were obtained, some modifications were made to the experiments.

Management of the project proved to be very difficult at times. In particular, there were difficulties because of the number of different parties involved in the project. Besides the NewLantic Group, there were three principal parties, each of whom had its own objectives for the study:

- The Department of Fisheries and Oceans initiated the project as a means to assist Newfoundland fish processing companies.
- Baader North America Inc. hoped that, should the concept prove to be feasible, there would be sales of additional machines.
- FPI although interested in the results of the experiment, wanted the least possible disruption of processing activity, and required production information confidential.

While the project required controlled experiments, these experiments had to be conducted during normal processing operations.

EQUIPMENT DESIGN

The sorting equipment used was a modified Scangrader, Model 481. Since the machine was to be used for sorting raw materials prior to processing, a rate of throughput approximating regular plant throughput was considered to be required. However, the length of the items - particularly cod - to be sorted would be considerably longer than that for which the machine was designed. The machine could have been modified to sort cod by weight but a longer weighing conveyor would have been needed and that would have resulted in an even lower rate of throughput than the regular model of the machine. It would also have increased the cost of the machine.

Sizing by length, instead of weight, offered an opportunity to increase the overall rate of throughput. Because fish are irregular in shape, use of a length measuring device was considered to provide less accuracy in sizing. Nevertheless, it was considered that obtaining a higher rate of throughput would be more important to establishing the feasibility of mechanized sizing for raw materials. Furthermore since raw materials and not finished products were to be sized, the degree of inaccuracy expected was not considered to be a serious problem.

Using a length measurement mechanism, throughput is limited only by the requirement that adequate space be maintained between successive items to ensure that two items are not measured at the same time. Accordingly, the regular 481 Scangrader was modified so that sorting was done by length of fish, rather than weight. Fish could be fed onto the conveyor belt with a minimum of 100 mm of space between them, irrespective of their length or weight. That distance is considerably shorter than would have been the

case, if measurements were done on the basis of weight, allowing more fish to be sized in a given period of time.

The modified Scangrader system used consisted of a computer for controlling operation of the system, electronic sensors for measuring the length of fish passing in front of them, a conveyor belt for transporting fish past the sensors, ejector arms for directing fish off the conveyor belt at appropriate locations according to their size and chutes for directing fish into containers after they were removed from the belt. Its principal characteristics are summarized in Table 1. The computer was the most critical component of the overall system, since it interpreted the signals sent to it from the electronic sensors and controlled the action of the ejector arms.

With the length measuring system, the computer could be programmed by the user to perform three basic functions:

- Sorting items according to prescribed length limits.
- Counting items within prescribed length limits into batches.
- Weighing items into batches of prescribed minimum weight, when the items are within prescribed length limits.

Within these three basic functions, a user could define up to 30 specific programs to accommodate production requirements.

For each of the programs, two types of input data were required. Data of the first type were stored permanently and used for signalling the appropriate ejector arm at the correct time. These data were entered as part of a set-up program and are illustrated in Figure 1. Data of the second type were specific to particular sizing requirements - for example,

TABLE 1 - MODIFIED 481 SCANGRADER CONFIGURATION

1. Overall length, excluding directional chutes: 6,400 mm

2. Overall width, excluding directional chutes: 400 mm

3. Height to separator belt: 1,500 mm

4. Power supply:

   - sizing machine: 3 phase, 575 volts, 60 hertz
   - computer: single phase, 120 volts, 60 hertz

5. Water supply:

   12mm (1/2") hose consuming a maximum of 2 litres/minute at 2 bar pressure

6. Air supply:

   6mm (1/4") hose consuming a maximum of 35 litres/minute dry clean air at 6 bar pressure

7. Temperature range:

   5° to 40°C

8. Separator belt velocity:

   79.7 m/minute

9. Theoretical maximum measuring rate:

   106 items/minute at a length of 650 mm/per item
   160 items/minute at a length of 450 mm/per item

10. Number of separator positions:

    4, not including the position off the end, which is usually used for over/under items

11. Computer user programs:

    - Sorting according to keyed-in length limits.
    - Counting items within keyed-in length limits into batches, with the number of items per batch also keyed-in.
    - Weighing of items within keyed-in length limits into batches of keyed-in minimum weight (threshold weighing).

    Weights are calculated by the computer from a conversion formula entered for each program.

Distance from photo detector 1 to hitpoint arm 1 (mm)	Distance between photo detector 2 and photo detector 1 (mm)	Distance belt moves when photo registration is shut off after any change (mm)	Belt velocity (mm)
Relative compensation			
Maximum item length (mm)	Minimum distance between items, front edge to front edge (mm)	Minimum distance between items, rear edge to edge (mm)	Distance belt moves when arm is out
Number of bins allotted	Not defined key in 1	Not defined key in 1	Not defined key in 1
Distance between arm 1 and arm 2 (mm)	Distance between arm 2 and arm 3 (mm)	Distance between arm 3 and arm 4 (mm)	Distance between arm 4 and arm 5 (mm)
Distance between arm 5 and arm 6 (mm)	Distance between arm 6 and arm 7 (mm)	Distance between arm 7 and arm 8 (mm)	

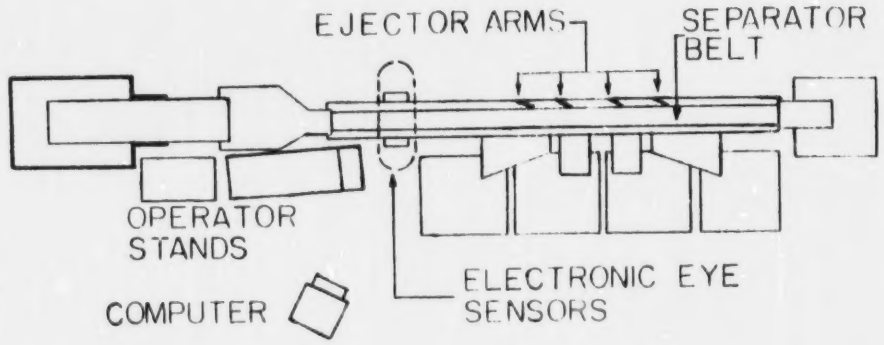
FIG. 1 - SYSTEM ESTABLISHED FOR LENGTH MEASUREMENT PROGRAM LENGB1050

the length ranges into which any one batch of fish were to be sized. Each size range had to have prescribed upper and lower limits, with the upper limit of one size being equivalent to the lower limit of the next larger size. Entries of both types of data into the system could be made through an attached terminal with a keyboard and a one-line display.

For carrying out the experiments, the Scangrader was incorporated into an overall system which consisted of a hopper/incline conveyor, a feeding chute for directing fish from the incline conveyor to the operator, operator stands and insulated containers for collecting sorted fish. A diagram of the system showing both plan and elevation views is provided in Figure 2.

EQUIPMENT OPERATION

In using the sorting equipment, de-iced whole fish in insulated fish containers were transported to the machine by a forklift. They were dumped from the containers into the hopper at the infeed end of the machine. An incline conveyor then carried the fish from the hopper to the feeding chute. As the system was set up, the operator was provided with a foot pedal to control the flow of fish to the feeding chute, to prevent overflowing of the chute. The feeding chute sloped toward the operator. The opreator slid each fish headfirst onto the sorting machine's separator belt, maintaining a minimum of 100 mm between fish. The discharge end of the feeding chute was at the same elevation as the sizing conveyor for easy transfer of fish from the chute to the conveyor.



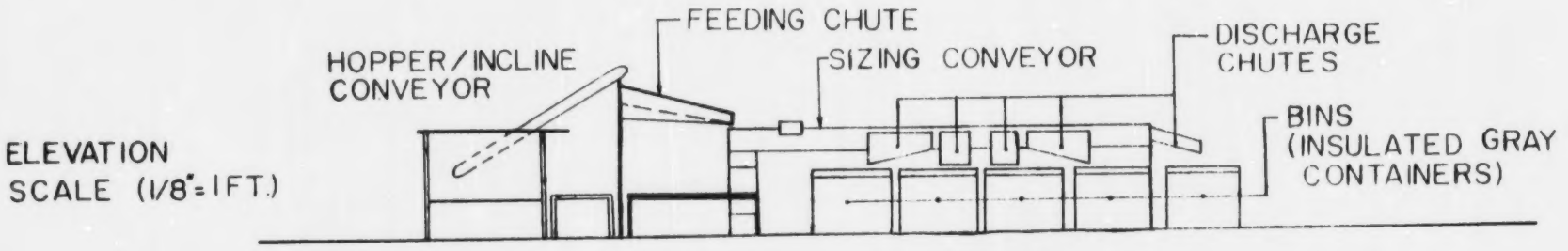


FIG.2 LAYOUT OF THE SYSTEM USED DURING EXPERIMENTS

After being put on the belt, fish were taken past two electronic eye sensors spaced approximately 92 mm apart. The sensor closer to the infeed chute was positioned 15 mm above the belt surface and the second sensor was positioned very close to the belt surface. Locating the sensors at different heights allowed for more accurate measurement, because of the irregular shapes of fish.

As fish passed in front of the sensors, they caused a light circuit in each sensor to be broken. The computer was then able to calculate the length of the object from the time period during which the circuit was interrupted. In order for the measurement to be accurate, the separator belt had to move at a constant speed.

Based on the length calculated for a fish as it passed in front of the optical sensors, a signal would be sent to one of the ejector arms, which would then sweep across the belt at an angle to direct the fish off the belt. when they left the belt, fish would slide into discharge chutes and be directed into containers used for collecting similarly-sized fish. During the experiments, the containers used were standard insulated fish containers, with base dimensions of 120 mm x 107 mm (48" x 43") and a height of 91 mm (36½"). Each of these containers had a holding capacity of approximately 454 kg (1,000 lbs.) of whole fish.

On occasion, the length of an item detected through the sensors did not coincide with the programmed limits, so the computer was unable to interpret the information. When that happened, the computer emitted an audible warning signal and displayed an error message that:

- an item was too short,
- an items was too long, or
- the distance between items was too short.

The machine had four ejector arms for directing sized fish off the conveyor belt, allowing fish to be separated into four distinct size ranges. Any fish outside the prescribed size ranges or for which errors were detected simply travelled the full length of the belt and fell into a container at the end. When a container was filled with fish, the machine had to stop, until the filled container could be removed and an empty container put in its place by a forklift. Replacing containers filled with fish usually meant a five-minute delay.

Sometimes, however, it was possible to use more than one ejector arm for the same size range. With this arrangement, the fish in the appropriate size range would first be directed into one container. The computer could be programmed to determine when that container was full and then divert fish of the same size to another position. As fish were being channelled into the second container, a forklift could remove the filled container and replace it with one that was empty, permitting the machine to be operated without interruption.

Delays occurred quite often in using the machine, due to difficulties in both keeping the machine supplied with fish and removing filled containers of sorted fish from the machine. These delays occurred either because sufficient insulated containers were not available or the forklift used for handling containers was occupied with other activities or space was rather limited making it difficult for the forklift to replace filled

containers efficiently. Such delays would not likely be a problem, if the machine was incorporated into an appropriately designed production system. In this case too, there should not be significant problems in keeping the machine supplied with fish. Its requirements for raw materials would be very similar to the requirements that presently exist for feeding fish into processing lines. Some delays occurred during the project because the operator of the forklift was also required to perform other production-related duties, while the experiments were being carried out. This would not be a problem with a forklift and operator dedicated to the task. Other problems encountered during the experiments could be overcome by replacing the hopper/incline conveyor used with one larger in size and better designed for proper de-icing of fish. The main difficulty expected would be in removing filled containers of sorted fish from the machine.

During the experiments, both cod and flatfish were sized into five categories, because only five positions were available for collecting fish from the machine. Four of these positions were in front of the conveyor belt and one was at the end, as illustrated in Figure 2. It was found that the arrangement that worked best was to use three of the four bins in front of the belt to collect fish within prescribed ranges and the fourth bin as a second container for the most common size being sorted. Fish which were both smaller and larger than the prescribed sizes would then fall into the fifth container, at the end of the separator belt, and would be separated later. This arrangement worked very well, because it gave the forklift operator time to replace the container filled with the most common size of fish with an empty container, without having to stop sorting. Bins used for fish of less common sizes did not have to be replaced as frequently.

Fish which fell into the container at the end of the belt were not actually sized. They were only recognized as not being wihin prescribed size ranges. In some cases, they represented errors, as were outlined earlier. Accordingly, fish falling into the container in that position had to be re-sized, usually in a special run at the end of the shift, during which the size ranges into which fish were being sorted would be reprogrammed to suit the characteristics of these fish. Although both large and small sizes were collected in that container, the combined weight of these fish was usually less than that accumulated at any of the positions.

The machine used during the experiments was built specifically for this project. However, it was not necessarily designed to suit normal production requirements. Difficulties found with the design features of the machine included the following:

1. The separator belt was not wide enough for large flatfish.
2. The ejector arms were not spaced properly for the insulated containers used for collecting sorted fish, necessitating use of chutes for directing fish discharged from the belt into the containers, but fish frequently became jammed in these discharge chutes.
3. The motion of the ejector arms sometimes resulted in the separator belt being dislocated from its track, particularly during the sizing of flatfish species.
4. The electronic eye sensors used to measure the length of fish sometimes became inoperative, because of ice or fish parts remaining in front of them.

5. The system for removing water from the air lines often did not work well.

RESULTS

Experiments conducted were of two basic types, as follows:

1. Sorting whole fish by size.
2. Processing fish which were either segregated by size or of mixed sizes.

MACHINE SORTING BY SIZE

Experiments were performed with the modified Scangrader Model 481 to determine:

- The rate of throughput that could realistically be expected.
- The accuracy of the machine in sizing whole fish.
- The suitability of the machine for sizing whole fish under production conditions.

Different size categories were defined, based on:

- The sizes in which whole fish are commonly purchased.
- Size ranges specified in design criteria for heading and filleting machines.
- Size ranges used by processors for packing finished products.

The limits of the size ranges selected are shown in Table 2.

To determine the rate of throughput that could realistically be expected for sorting each size of fish, experiments were performed using fish that had previously been sized. Either one or two operators would feed fish through the machine and observations of the activity were

conducted using customary industrial engineering time study methods. Results were then adjusted according to the usual manner for making adjustments in time study data to derive throughput rates which could be expected during work over an extended period of time. These results are presented in Table 3.

It should be noted that the throughput rates shown in Table 3 are for each size of fish independently, determined from experiments involving feeding only fish of the relevant size range through the machine. In that sense, the experiments did not measure the rates of throughput for sorting fish but the rates of throughput for fish within a single size category. Actual requirements for sorting are variable, depending on the mix of sizes contained in a batch to be sorted. The actual throughput rate that can be expected in any given situation will, therefore, depend on the mix of characteristics of the fish to be put through the machine.

For a single operator, the rate of throughput ranged from a low of 42.7 whole fish per minute to a high of 71.3 fish per minute, depending on the size of fish. Both the highest and the lowest rates were achieved in sorting cod. Throughput rates for sorting flatfish species of different sizes fell within that overall range. The rates determined are reasonably consistent with observations made by the NewLantic Group in other work, where a single operator is required to feed items onto a moving belt, one after another, without overlapping, and where the speed of the belt is not a restriction. In that other work, it has been found that an operator's rate of throughput will generally vary from 40 to 80 pieces per minute, depending on the size of the individual pieces, the ergonomic design features of the system and the skill of the operator.

TABLE 2 - LIMITS OF FISH SIZE CATEGORIES USED DURING THE EXPERIMENTS

SPECIES	MM		INCHES	
	LOW	HIGH	LOW	HIGH
Flatfish				
- Size 0	Less than 260		(Less than 10 1/4)	
- Size 1	260	345	(10 1/4	13 1/2)
- Size 2	345	400	(13 1/2	15 3/4)
- Size 3	400	450	(15 3/4	17 3/4)
- Size 4	Greater than 450		(Greater than 17 3/4)	
Codfish				
- Size 1	Less than 495		(Less than 19 1/2)	
- Size 2	495	585	(19 1/2	23)
- Size 3	585	650	(23	25 1/2)
- Size 4	650	710	(25 1/2	28)
- Size 5	Greater than 710		(Greater than 28)	

NOTE: Length measurements were made from head to meat of tail.

TABLE 3 - THROUGHPUT RATES FOR MANUALLY FEEDING WHOLE FISH THROUGH A SCANGRADER LENGTH SIZING MACHINE

	PIECES/MINUTE	
	1 OPERATOR	2 OPERATORS
FLATFISH		
- Size 0	69.1	84.9
- Size 1	64.3	79.0
- Size 2	59.7	73.0
- Size 3	54.6	67.2
- Size 4	48.4	61.2
CODFISH		
- Size 1	71.3	78.7
- Size 2	62.4	69.5
- Size 3	54.4	60.4
- Size 4	48.5	53.9
- Size 5	42.7	48.1

NOTE: The throughput rates above include a 15% allowance for operator fatigue and incidental machine delays. No time is included for delays such as:

- keeping the machine supplied with fish, or
- taking sized fish from the machine.

Since the speed of the operator was the factor limiting the overall rate of throughput, some additional experiments were carried out during which a second operator was added. Results of these experiments are also shown in Table 3. For flatfish, the second operator was able to increase the overall rate of throughput by approximately 25% but, for cod, the second operator resulted in an improvement of only about 10%.

Table 3 gives the estimated rate of throughput in terms of fish per minute for each size of fish. Fish in the different size categories are very different in weight (Table 4). In Table 5, the rates in Table 3 were used to derive an estimated rate of throughput for the machine, calculated in weight of fish sorted over a full eight hour production shift, recognizing differences in the weight of fish in different size categories. The rates indicated in Tables 3 and 5 assume that no delays occur in keeping the machine supplied with fish or in taking filled containers of sorted fish away from the machine.

The accuracy of the machine in sizing whole fish was tested by feeding fish previously sized through the machine a second time. During the second run, the length limits used by the computer program to control the sizing mechanism were expanded by either 12mm or 25mm (½" or 1") at each end of the range. For example, the normal length limits established for flatfish of size two - 34cm to 40cm (13½" to 15 3/4") - were expanded by 12mm (½") at each end to become 33cm to 41cm (13" to 16 1/4"). This was done to allow for small differences in measured length between runs, because of variability in alignment of the fish on the conveyor belt. Results of these experiments are presented in Table 6.

TABLE 4 - WEIGHT .LB., FOR EACH SIZE CATEGORY OF WHOLE FISH USED DURING THE EXPERIMENTS

SPECIES BY SIZE	LOW	HIGH	AVERAGE
Witch Flounder (Greysole) - Round			
- Size 0	-	.46	.36
- Size 1	.46	.89	.65
- Size 2	.89	1.41	1.11
- Size 3	1.41	2.25	1.77
- Size 4	2.25	-	2.75
American Plaice (Grey Coloured) - Gutted			
- Size 0	-	.63	.44
- Size 1	.63	1.35	.95
- Size 2	1.35	2.15	1.71
- Size 3	2.15	3.50	2.70
- Size 4	3.50	-	4.40
American Plaice (Black Coloured) - Gutted			
- Size 0	-	.54	.39
- Size 1	0.54	1.24	.88
- Size 2	1.24	1.85	1.53
- Size 3	1.85	2.63	2.20
- Size 4	2.63	-	3.28
Yellowtail Flounder - Gutted			
- Size 0	-	.69	.56
- Size 1	.69	1.39	.99
- Size 2	1.39	2.15	1.74
- Size 3	2.15	3.21	2.63
- Size 4	3.21	-	3.85
Cod - Gutted			
- Size 1	-	3.03	2.53
- Size 2	3.03	4.46	3.68
- Size 3	4.46	5.78	5.06
- Size 4	5.78	7.37	6.49
- Size 5	7.37	-	8.80

NOTES:
1. The low and high weights are derived from the length-weight established during the project.
2. The average weights are based on the weight of fish in each size category fed to the processing lines during the study.
3. Lb. x 0.4536 = kg.

TABLE 5 - ESTIMATED THROUGHPUT RATE' LB. PER SHIFT FOR MANUALLY FEEDING WHOLE FISH THROUGH A SCANGRADER LENGTH SIZING MACHINE

SPECIES/SIZE	AVERAGE ITEM WEIGHT, LB.	1 OPERATOR	2 OPERATOR
Witch Flounder (Greysole)			
- Size 0	0.36	11,194	13,754
- Size 1	0.65	18,808	23,108
- Size 2	1.11	29,820	36,464
- Size 3	1.77	43,489	53,525
- Size 4	2.75	59,895	75,735
- Weighted Average	1.38	34,938	43,040
American Plaice (Grey Colour)			
- Size 0	0.44	13,682	16,810
- Size 1	0.95	27,488	33,773
- Size 2	1.71	45,939	56,174
- Size 3	2.70	66,339	81,648
- Size 4	4.40	95,832	121,176
- Weighted Average	1.91	48,643	60,026
American Plaice (Black Colour)			
- Size 0	0.39	12,127	14,900
- Size 1	0.88	25,463	31,284
- Size 2	1.53	41,103	50,261
- Size 3	2.20	54,054	66,528
- Size 4	3.28	71,438	90,331
- Weighted Average	1.04	28,835	35,424
Yellowtail Flounder - Gutted			
- Size 0	0.56	17,413	21,395
- Size 1	0.99	28,646	35,195
- Size 2	1.74	46,745	57,159
- Size 3	2.63	64,619	79,531
- Size 4	3.85	83,853	106,029
- Weighted Average	1.24	34,413	42,224
Cod - Gutted			
- Size 0	2.53	81,175	89,600
- Size 1	3.68	103,334	115,092
- Size 2	5.06	123,869	137,531
- Size 3	6.49	141,644	157,415
- Size 4	8.80	169,092	190,476
- Weighted Average	3.58	99,530	110,466

NOTES: 1. The average item weight is calculated from the distribution of whole fish received at the plant during the experiments.

2. A shift is assumed to be 8 hours in duration, of which 450 minutes are worked.

3. Lb. x 0.4536 = kg.

TABLE 6 - COMPARATIVE ACCURACY IN SORTING WHOLE FISH BY THE MODIFIED SCANGRADER LENGTH SIZING MACHINE AND ITS OPERATOR, BASED ON THE NUMBER OF FISH SORTED

	LEVEL OF PERFORMANCE				
	MACHINE			COMBINED	
SPECIES BY SIZE	±½" TOLERANCE	±1" TOLERANCE	OPERATOR	±½" TOLERANCE	±1" TOLERANCE
Flatfish					
- Size 0	99.0	100.0	98.0	97.0	98.0
- Size 1	97.6	100.0	98.0	95.6	98.0
- Size 2	97.8	100.0	97.9	95.7	97.9
- Size 3	96.3	100.0	98.4	94.8	98.4
- Size 4	71.3	95.0	94.9	67.7	90.2
Codfish					
- Size 1	87.7	100.0	98.6	86.5	98.6
- Size 2	87.6	100.0	98.6	86.4	98.6
- Size 3	79.9	95.0	94.7	75.7	90.0
- Size 4	70.5	90.0	76.2	53.8	68.6
- Size 5	N/A	N/A	N/A	40.0	50.0

NOTE: The data for codfish, size 5 are estimated.

Overall, the accuracy was found to depend on both the machine and the operator feeding it. Errors attributable to the machine itself were found to be due to:

- Irregularities in the shape of the fish, such as its head or tail not being flat against the belt surface.
- Foreign material, such as fish parts or ice, blocking the length sensing mechanisms.

Errors caused by the operator were due to:

- Separation between successive fish being less than 100 mm.
- Failure to align the fish parallel to the direction of travel of the separator belt.

The results given in Table 6 indicate that the level of performance deteriorated with increasing size of fish. For example, the largest error rate was for cod larger than 65cm (25½"). However, it may be worth noting that the tolerances of 12mm (½") and 25mm (1") used in the second sizing run represented progressively smaller proportions of the overall length of a fish, as the fish increased in size. In other words, 12mm (½") represents a much higher proportion of the length of a small fish than it does the length of a larger fish. Accordingly, the fixed nature of the tolerances actually represented a tighter requirement for fish that were larger in size. It can also be observed that large fish customarily represent a relatively small proportion of the total catch.

Larger fish make up a greater proportion of the weight of a catch than they do of the numbers of fish in the catch. Based on the data in Table 7 and the average weight of fish (Table 4), in each size range, Table 8 was

TABLE 7 - DISTRIBUTION, BY SIZE, OF FISH RECEIVED AT THE PLANT DURING THE EXPERIMENTS BASED ON THE NUMBER OF FISH SORTED

SPECIES BY SIZE	%
Witch Flounder (Greysole)	
- Size 0	1.4
- Size 1	12.5
- Size 2	45.8
- Size 3	32.7
- Size 4	7.6
American Plaice (Grey Coloured)	
- Size 0	0.5
- Size 1	33.6
- Size 2	35.2
- Size 3	21.2
- Size 4	9.5
American Plaice (Black Coloured)	
- Size 0	7.4
- Size 1	70.7
- Size 2	16.3
- Size 3	4.4
- Size 4	1.2
Yellowtail Flounder	
- Size 0	5.0
- Size 1	64.7
- Size 2	25.9
- Size 3	4.1
- Size 4	0.3
Cod	
- Size 1	40.6
- Size 2	40.8
- Size 3	11.8
- Size 4	6.2
- Size 5	0.6

TABLE 8 - DISTRIBUTION, BY SIZE, OF FISH RECEIVED AT THE PLANT DURING THE EXPERIMENTS BASED ON THE WEIGHT OF FISH SORTED

SPECIES BY SIZE	%
Witch Flounder (Greysole)	
- Size 0	0.4
- Size 1	5.9
- Size 2	36.8
- Size 3	41.9
- Size 4	15.0
American Plaice (Grey Coloured)	
- Size 0	0.1
- Size 1	16.7
- Size 2	31.5
- Size 3	29.9
- Size 4	21.8
American Plaice (Black Coloured)	
- Size 0	2.8
- Size 1	60.0
- Size 2	24.1
- Size 3	9.3
- Size 4	3.8
Yellowtail Flounder	
- Size 0	2.3
- Size 1	51.7
- Size 2	36.4
- Size 3	8.7
- Size 4	0.9
Cod	
- Size 1	28.7
- Size 2	41.9
- Size 3	16.7
- Size 4	11.2
- Size 5	1.5

derived to show the distribution of the weight of fish landed, by size category.

PROCESSING FISH

Results from processing fish in a limited size range were compared to results from processing fish of mixed sizes:

- Fish were sorted into defined size ranges.
- Batches of fish from each size range were processed and the results were recorded.
- Batches of mixed sizes were made up from sized fish, so the proportions of fish of different sizes contained in the missed batches were known.
- Results from processing sized fish were used to project the results that would be expected from the mixed batches.
- Actual results from processing the mixed batches were compared with the projection.

On any one shift during which experiments were performed, it was attempted to process both batches of fish that were within particular size categories and a batch drawn from the same source that were of mixed sizes. Each group of experiments was intended to be completed during a single shift, to minimize any impact on the results of using fish from different sources, having processing activities performed by different people, or doing the processing under different conditions.

It was attempted to use batches of 2,000 to 4,000 lbs. as a good compromise among the considerations of:

- Allowing several different batches to be processed during a single production shift.

- Minimizing the effects of changeovers from one batch to another.
- Approximating realistic production conditions.

All fish sent through the production lines during the processing experiments were sorted by size using the Scangrader. However, in order to make up a full batch of fish in any one size category, many more fish had to be sized than would be included in the batch. Accordingly, fish were sorted by size the day before they were processed. Fish included in batches of mixed sizes were first sorted into their respective size categories. Then, fish of different sizes were mixed together in known proportions, in order to control the degree of variability in the batches. Each container filled with fish to be processed was tagged and stored in a designated area in the holding room, where it could be accessed quickly, when required.

Up to 50 production workers were involved in processing each batch. One slip, even by a single production worker, could mean an impairment in the validity of information collected from the experiment and, perhaps, even a full day's work. Often, it was difficult to coordinate all of the activities and ensure smooth flow, without slowing down or otherwise interferring with production.

Each experiment was conducted completely separate from other experiments, in order to ensure the integrity of the information collected. For each experiment involving filleting of flatfish by machine, the following information was collected as fish passed through the production lines:

1. Weight data for
   - the weight of fish fed to the heading machines,
   - weight of skin-on fillets from the filleting machines, including the weight of fillets by back and belly side, and
   - weight of trimmed fillets from the trimming tables, by pack type.
2. Time data, including
   - time worked by operators of heading filleting, and skinning machines and by trimmers; and
3. Quality data, including
   - checks of the quality of skinned fillets to the trimming table, commonly referred to as work content checks, and
   - checks of the quality of trimmed fillets from the trimming tables, by worker and final product.

Experiments for this purpose proved to be extremely difficult to run under production conditions. Problems were continually encountered, due to:

- environmental conditions,
- mechanical breakdowns,
- shortage of raw materials, and
- a requirement that fish not be held for an extended period of time prior to processing, in order to avoid significant quality deterioration.

Because of these difficulties, compromises sometimes had to be made. At times, batches were less than the desired minimum of 2,000 lbs. On some days, processing could not be completed on all of the batches intended to be processed. Although compromises were a necessity, considering the

situation, it is not felt that the results are significantly less valid than they would have been if these compromises had not been made, for reasons which will be discussed later.

Data collected during the experiments are summarized in Tables 9.

Data adjusted for presentation purposes to show differences; absolute values are not provided, because of a need for confidentiality. The yield of trimmed fillets from whole flatfish obtained using a production line made up of a Baader 175 heading and filleting machine and two Baader 47 skinning machines showed a 1.2% to 1.9% increase in yield when whole fish were sized, compared to results obtained from processing fish of mixed sizes; and

1. Yields for witch flounder (greysole) filleted by machine were significantly lower for fish in size category one than they were for fish in size categories two, three, and four (Figure 3);
2. Yields from grey American plaice were considerably higher than those for black fish of the same species (Table 10); and
3. Rates of throughput, measured in lbs./hour, vary substantially by size of fish, with higher throughput rates being achieved during processing of larger fish (Figure 4).

IMPACT OF EXPERIMENTAL CONDITIONS ON THE RESULTS

Processing fish is a dynamic activity, which requires production management personnel to respond quickly to changes in raw material characteristics, production conditions, and performance of workers and machines in carrying out processing activities. Despite the best efforts

TABLE 9 - YIELDS OF TRIMMED FILLETS FROM WHOLE FISH: ACTUAL RESULTS FOR FISH OF MIXED SIZES COMPARED WITH RESULTS FOR SIZED FISH

	ACTUAL YIELD (Mixed Fish)	PROJECTED YIELD (Size-Sorted Fish)		IMPROVEMENT IN YIELD (Difference)	
		SAME DAY	OVERALL AVERAGE	SAME DAY	OVERALL AVERAGE
FLATFISH FILLETED BY MACHINE					
Witch Flounder (Greysole)					
- March 13	0.9	-	3.0	-	2.1
14	1.1	3.0	2.9	1.9	1.8
Average					1.9
American Plaice (Grey)					
- March 13	-0.7	0.4	-0.4	1.1	0.3
20	-3.4	-1.4	-0.3	2.0	3.1
21	-1.0	-0.4	-0.6	0.6	0.4
Average				1.2	1.2
American Plaice (Black)					
- March 27	-1.6	-0.1	-	1.5	-
COD FILLETED MANUALLY					
- March 21	3.0	3.3	3.8	0.3	0.8
27	3.7	-	3.2	-	-0.5
Average					0.1

NOTES: 1. For presentation purposes, all yields are calculated in relative terms only by deducting from the actual results the average yields obtained in processing fish of size 1 of the same species.

2. Actual results indicated above are the actual results obtained from processing batches of fish containing a mixture of sizes, in which the quantities of fish in each size category were known. These actual results are then compared with the results that could have been expected if the fish in the mixed batches had been sorted by size, based on projections using results from processing of batches of sized fish.

TABLE 10 - AMOUNTS BY WHICH TRIMMED FILLET YIELD FROM WHOLE GREY AMERICAN PLAICE EXCEED YIELD FROM BLACK AMERICAN PLAICE IN DIFFERENT SIZE CATEGORIES

SIZE CATEGORY	YIELD DIFFERENCE
1	5.7
2	5.2
3	5.3

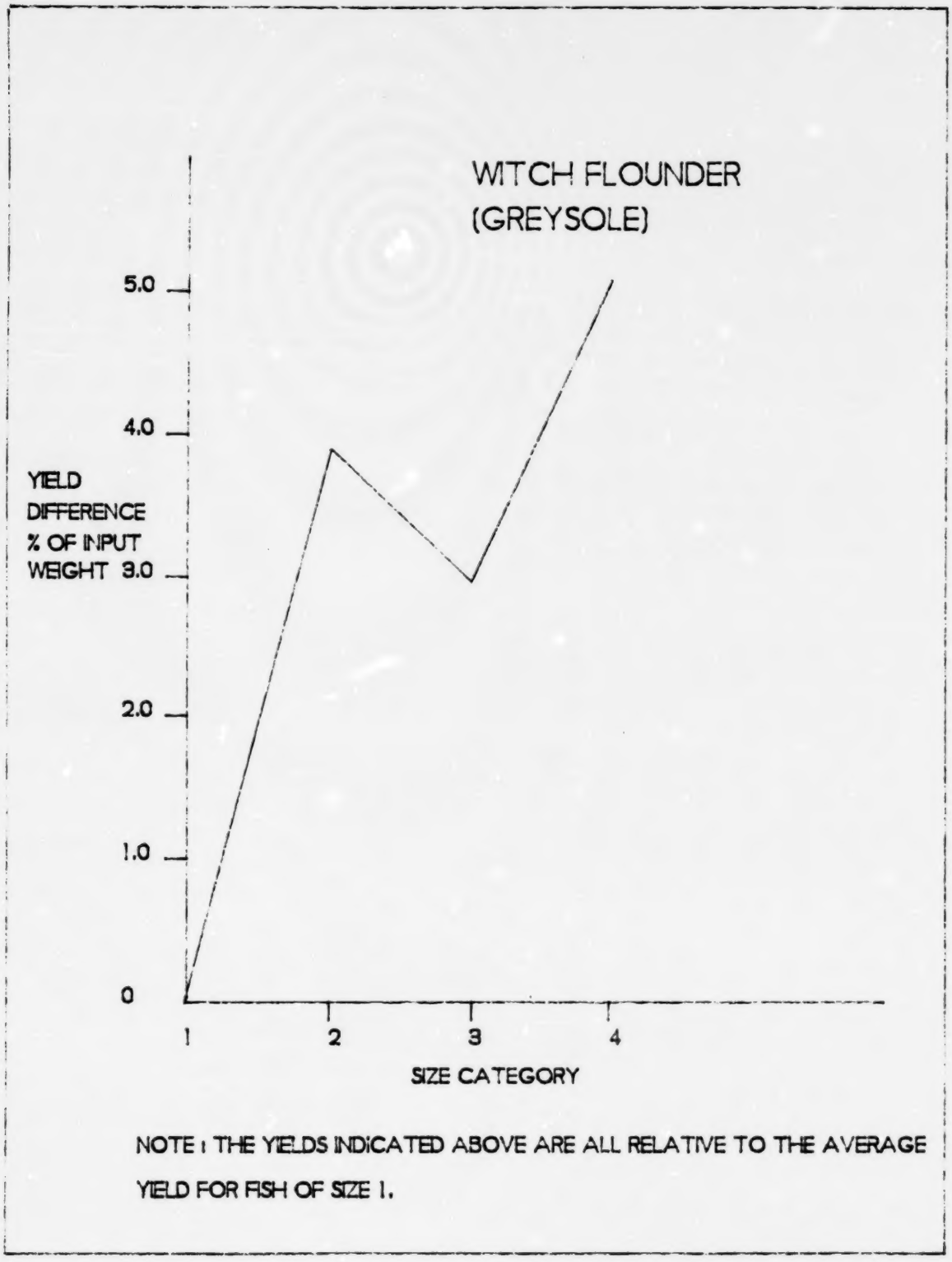


FIG.3 RELATIONSHIP BETWEEN YIELD (OF TRIMMED FILLETS FROM WHOLE FISH)
AND SIZE OF FISH .

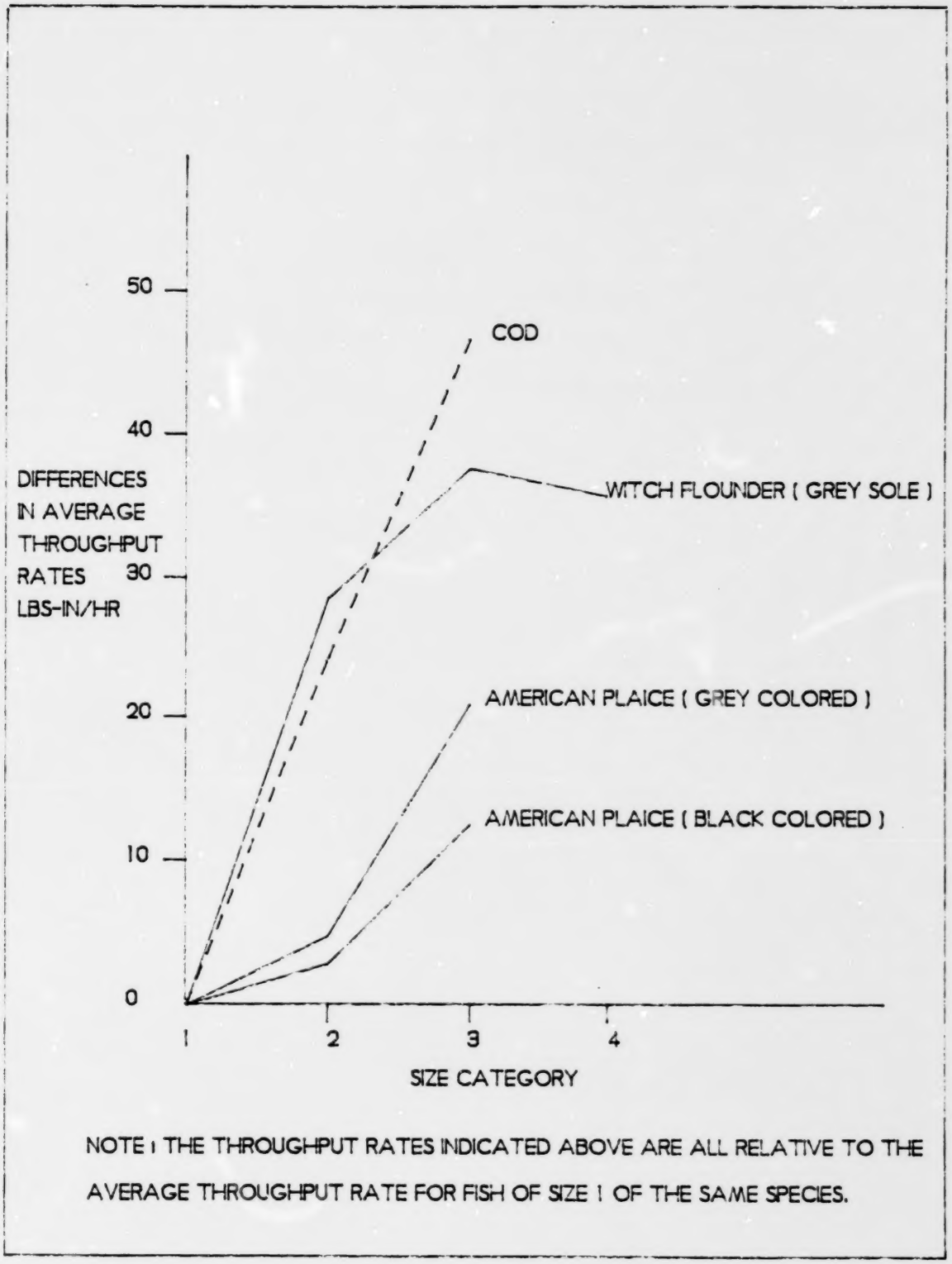


FIG.4 RELATIONSHIP BETWEEN THROUGHPUT RATE AND SIZE OF FISH.

of everyone involved in the project to ensure that conditions were controlled and activities were coordinate, the variability inherent in processing fish often resulted in inability to maintain complete control over conditions throughout the period during which an experiment was being conducted.

In some ways, it might have been better to use smaller batches of fish in carrying out the processing experiments, because there would have been less likelihood of changes in conditions during the period of any one experiment. However, budget, time and other limitations made this impossible.

Limitations in the program of experiments created by the fact that they had to be run in a production setting did not allow all the benefits from sorting to be identified or quantified satisfactorily. If further research is to be done into the benefit/cost relationships of sorting fish by size, one approach which could be used is to perform the experiments in a laboratory environment, in order to allow conditions to be more controlled than they were during the experiments done as part of this project. However, to allow definitive conclusions to be drawn, it is expected that a relatively large number of experiments would have to be conducted over a considerable period of time and under a variety of different conditions. Accordingly, a much larger budget for such research would be needed than was available for this project.

PRODUCT SYSTEM DESIGN

Machines are designed to follow exactly the same pattern of operations in a repetitive cycle, so they are highly consistent in what they do. Inconsistency may creep in at times due to wear and tear in moving parts, so repairs and maintenance are needed to keep them up to their design capabilities. However, if they are properly maintained, the principal source of inconsistency in production performance is likely to be inconsistency in the raw materials processed.

Results obtained from the experiments carried out during this project indicate that higher yields can indeed be expected from sorting flatfish by size prior to processing them with a Baader 175 heading and filleting machine. Yield benefits should also be expected from sorting cod by size prior to processing them on older model machines. However, the yield benefits likely to be obtained from sorting cod prior to processing them on the Baader 426/184 or 427/185 equipment would, at best, be much lower in their order of magnitude, because the machines are self-adjusting over a fairly large range of fish sizes. Since these machines represent the current state of the art for design of such equipment, it is likely that they would be the models adopted for use by Newfoundland fish processing companies in the future, if they were to change from hand to machine filleting.

Since human beings are able to adjust to differing processing requirements more easily than machines, workers employed to fillet fish by hand are not necessarily affected to the same degree as machines, when they are required to process fish in different size ranges. Based on the

results obtained during this study, there appears to be little value, if any, in sorting fish by size prior to a manual filleting process. There could still be benefits available through better and more consistent performance by switching from hand filleting to machine filleting.

COMPLEXITY CAUSED BY THE MIX OF OUTPUT PRODUCTS

As fish processing companies have increased their production of fillet packs from Atlantic groundfish, the number of categories of products available to be produced has also increased. Because of the greater variety of products available, managing the mix of products to achieve optimum value from raw materials - while also ensuring that each product conforms to specified requirements - has become much more complex than it was. Furthermore, the tasks required of production workers have also become much more complex.

Grading/pack allocation decisions involve judging the best way to allocate a single fillet into individual product packs to achieve the best value from it. These decisions are constrained by both the characteristics of the fillet and the number of alternative products available for production at any one time.

If fish could be sorted by size prior to putting them into the processing line, so that the need to sort by size at the trimming function would be eliminated or reduced, there should be considerable simplification of the trimming work function. Besides eliminating the need for sorting by size, it would simplify decisions related to sectioning of fish and sorting them by quality, as well, resulting in fewer pans being required for

collection of output materials. Simplification of the duties required of a trimmer might reasonably be expected to have the further consequences of higher throughput rates and lower instances of sorting errors.

Unfortunately, however, the mix of products being made from the raw materials processed during the project did not allow adequate testing of the benefits that might be available from work simplification.

During the project, most of the products were fillet portions, obtained from sectioning whole fillets. These portions were frozen with the IQF method and sorted mechanically by size after the freezing process. Accordingly, it was not possible to do a proper evaluation of the effects of product mix on work complexity or the rate of errors in allocation decisions.

RAW MATERIAL CHARACTERISTICS AND LINE BALANCING

Besides the effects on individual work functions, processing fish which has been sorted by size has a significant impact on the balancing of the rate of throughput at the different work stations on a processing line. Processing fish in batches of different sizes results in differing rates of throughput, measured in terms of weight per unit of time. These different rates of throughput require varying numbers of workers to be stationed at different work stations, in order to maintain a balanced overall rate of flow through the system.

When a batch of fish that are relatively consistent in size is being processed it is reasonably easy to obtain a balanced rate of flow. Similarly, when the batches are made up of more or less randomly mixed

sizes, there may be an averaging effect, also resulting in a reasonably balanced rate of flow. However, when the sizes of fish being processed vary so that fish in one size category are followed through the line by fish in a different category, an imbalanced situation is likely to occur.

When such an imbalance occurs, some people must be reassigned to restore a balanced flow, which is not always easy to do. This problem would be particularly difficult if there were many fluctuations in the sizes of fish processed during a single shift, because adjustments would have to be made continually in the numbers of workers stationed at the different functions, in order to keep the overall flow in balance.

LOCATIONS FOR SORTING

Probably the ideal location for sorting fish by size would be onboard fishing vessels, immediately after the fish are havested. This would allow fish to be sized before being stored in the hold. They could then be unloaded and weighed by size. However, problems with trying to implement such an approach include:

- extra work would be required of fishermen,
- considerable space would likely be required onboard fishing vessels for sorting, and
- suitable sizing equipment does not appear to be available.

Another option would be to sort all or part of the landings of a particular fish species at some point between the time of discharge from fishing vessels and when the fish are required for processing. With this approach, sorted fish would have to be de-iced for sorting and re-iced

prior to processing, so additional ice would be required. The fish would also have to be handled an extra time, which would result in additional labour costs and, possibly, lower quality. Benefits from sorting at this point would likely be greater utilization of the sorting equipment and possibilities to use technology with a lower rate of throughput than the rate required for sorting fish during discharge.

The practicality of this option would also likely depend on the situation at any one plant. For example, if the plant does not have a large holding shed, then the throughput rate required for sorting would have to approximate the rate of discharge, which is generally greater than the rate of processing throughput. Similarly, a plant operating at full capacity for two shifts per day would not likely obtain much benefit from sorting at this point.

In Newfoundland, the best location would be to sort the fish by size as they are being discharged from a fish vessel and sorted for weighing into the different size categories appropriate for purchasing. Some sizing is already done at this point, so all that would be required would be to expand and improve the sizing process. The main disadvantage of sizing at this location is that the rate of throughput required of a sizing process would have to equal the rate of discharge of raw materials from the fishing vessel. Typically, discharge rates range from 100,000 to 150,000 lbs. of fish per 8 hour shift at their minimum level and they can go much higher for highly automated systems. However, the choice of sorting location is likely to depend on the circumstances that exist at each plant.

MANUAL SORTING

Sorting fish by size onboard fishing vessels seems to be a somewhat futuristic concept at the present time. However, sorting fish as they are being discharged from fishing vessels is probably the next best alternative. At that location, sorting capacity would have to be a minimum of 15,000 lbs. per hour or 120,000 lbs. in an 8-hour shift. Methods expected to be able to meet that rate of throughput are discussed below.

In many Newfoundland fish plants, it has been customary to sort fish by size using a manual method, as was outlined earlier. With this method, fish are placed on a moving conveyor belt and they are inspected visually by workers stationed at different points along the belt. These workers pick out fish of odd species and/or sizes and allow the remainder to continue to the end of the belt. For example, if fish were distributed among three different size ranges, such that:

Size 1 = 10%

Size 2 = 60%, and

Size 3 = 30%,

then the 60% of the catch represented by size 2 would continue to the end of the belt, while workers would attempt to remove the other 40% of the fish from the belt and place them in separate containers. Workers generally have more difficulty sorting out fish in size categories that are close together but find it easier to sort fish that are very different in size. It is also easier to pick out the odd sizes if there are not many fish outside the required range than if fish are evenly distributed among several different size ranges. Table 11 shows estimates of the accuracy of

sizing fish manually. Inconsistencies in performance by workers result in variable levels of performance, so good, average and poor performance levels for manual sizing are shown in Table 12.

Because a machine measures the size of every fish, a greater proportion of the fish in sorted batches should be consistent in size after a mechanical sorting process. Nevertheless, there will still be some errors.

From Table 12, it can be observed that manual sorting of flatfish can increase quite considerably the proportions of fish in any one batch that are consistent in size. Even when sizing performance is poor, the proportion of fish that are consistent in size can be expected to be at least 25% greater than that for unsized fish. When performance is good, the proportion of consistently-sized fish can be expected approximately to double. Improvements in the consistency of sizes of cod can also be quite considerable, although the overall accuracy of sorting cod by size is somewhat less than the accuracy for sorting of flatfish, for both manual and machine sorting.

Based on the results of the experiments, an increase in yield of approximately 1% to 1.5% can be expected from filleting sized flatfish by machine. From Table 12 it could be further said that:

- 36% to 47% of that benefit, or 0.36% to 0.705% improvement in yield, could be realized from manual sizing, when the performance of the workers is poor,
- 56% to 66% of the benefit, or 0.56% to 0.99% improvement in yield, could be obtained from manual sizing, when the workers' performance is average, and/or

TABLE 11 - ACCURACY OF SORTING, BY FISH COUNT, WHEN MANUALLY SIZING WHOLE FISH

CRITERIA	LEVEL OF PERFORMANCE, % GOOD	AVERAGE	POOR
A. ABILITY TO REMOVE FISH FROM THE MAIN RUN			
- Flatfish			
±1 Size	80	65	50
±2 Sizes	90	80	70
- Codfish			
±1 Size	70	60	50
±2 Sizes	85	75	65
B. ABILITY TO CORRECTLY ASSIGN A FISH ONCE IT HAS BEEN REMOVED FROM THE MAIN RUN			
- Flatfish			
±1 Size	90	80	70
±2 Sizes or More	95	87.5	80
- Codfish			
±1 Size	80	70	60
±2 Sizes	90	80	70

NOTES: 1. Information obtained from
- inferences drawn from observations of manual sorting,
- data collected at the plant, and
- data obtained through other manual sorting experiments.

2. The main run is assumed to be the size with the largest percentage by count.

3. Worker's accuracy measured against a tolerance of ±½".

4. Performance levels assume that most fish are sized without checking against a measure. However, the worker has the option of checking all questionable fish.

TABLE 12 - PERCENTAGE OF WHOLE FISH WHICH ARE CONSISTENT IN SIZE BASED ON THE NUMBER OF FISH IN BATCHES OF MIXED SIZES SENT THROUGH THE PROCESSING LINES

	SIZED				
		MANUAL			
SPECIES	MACHINE	GOOD	AVERAGE	POOR	NON-SIZED
Witch Flounder (Greysole)					
- March 13/86	94.4	84.8	73.8	64.4	44.1
- March 14/86	93.6	86.7	76.3	67.2	43.3
American Plaice (Grey Coloured)					
- March 13/86	95.5	88.7	79.6	71.7	49.7
- March 20/86	95.5	88.2	78.9	70.9	50.3
- March 21/86	95.4	86.5	76.9	68.7	53.5
American Plaice (Black Coloured)					
- March 27/86	95.4	89.5	81.1	73.8	53.5
Cod					
- March 20/86	82.8	78.8	68.9	60.4	35.9
- March 21/86	84.0	80.8	72.6	65.5	45.7
- March 27/86	85.5	81.5	74.8	69.0	53.8

NOTES: 1. Machine and worker tolerances are assumed to be $\pm\frac{1}{2}$".

2. The size category with the largest percentage is assumed to be the main run for non-sized fish.

- 79% to 86% of the benefit, or 0.79% to 1.29% improvement in yield, could be obtained from good performance in manual sizing.

Although mechanical sorting by size offers a higher overall level of benefits, manual sizing also seems to be a reasonable method, considering its lower cost, provided that good performance can be achieved.

COST/BENEFIT ANALYSIS

Without being able either to quantify all of the benefits that might be available or identify the particular characteristics of equipment to be used for sorting, it is difficult to form definitive conclusions on the costs and benefits of sizing. Among the available altenratives, the Baader 486 is limited to fish of gadidae species, for which sizing seems to have limited benefits at best. Accordingly, the best technological approach (Table 13) to the problem would seem to be either the dual Scangrader or the machine developed by Grove Telecommunications Limited. Manual size-sorting can also continue to be used.

Tables 14 and 15 show a comparison of the projected costs of sorting fish by size, using the different approaches likely to be available in the short term. In Table 14, it is assumed that equipment would be used for 100 shifts each year. In Table 15, 200 shifts of annual usage are assumed.

The Baader 486 machine offers the lowest cost alternative but its value is limited, because it can be used only for gadidae species. After that, the lowest cost is for manual sorting, but the cost advantage for manual sizing is much less when mechanical sorting is used for 200 shifts annually instead of just 100 shifts.

TABLE 13 - ESTIMATED THROUGHPUT RATE PER SHIFT FOR MECHANICAL SORTING OF FISH BY SIZE USING TECHNOLOGY EXPECTED TO BE AVAILABLE IN THE SHORT TERM

SPECIES	AVERAGE WEIGHT OF FISH LB.	ESTIMATED THROUGHPUT PER SHIFT, LB.
Witch Flounder (Greysole)	1.38	108,675
American Plaice (Grey Coloured)	1.91	150,413
American Plaice (Black Coloured)	1.04	81,900
Yellowtail Flounder	1.24	97,650
Cod	3.58	201,375

NOTES:
1. Cod are assumed to be sorted by either the dual Scangrader or the Baader 486 but flatfish are assumed to be sorted by the dual Scangrader only, since the Baader 486 is not suitable for flatfish.
2. The number of pieces sorted per minute is assumed to be 175 for flatfish and 125 for cod.
3. The weighted average is calculated on the distribution of whole fish received at the plant during the experiments.
4. A shift is assumed to be 8 hours in duration of which 450 minutes are worked.

TABLE 14 - COST OF SIZING WHOLE FISH ASSUMING OPERATION FOR 100 SHIFTS/YEAR

	MACHINE		
	DUAL SCANGRADER	BAADER 486	MANUAL TABLE
1. Capital Cost	$150,000	$75,000	$25,000
2. Annual Costs			
- Amortization of capital cost at 12% per annum, over 10 years	25,526	12,763	4,254
- Maintenance (beginning 3rd year), 2% of Capital Cost	3,000	1,500	500
- Electricity	150	150	150
- Labour for sorting	13,600 (2)	-	20,400 (3)
- Labour for quality inspection	850 (1/8)	850 (1/8)	1,700 (¼)
Totals			
- Years 1 and 2	40,126	13,763	26,504
- Year 3 and subsequent years	43,126	15,263	27,004
3. Unit Cost, ¢/lb.			
- Years 1 and 2	0.33	0.11	0.22
- Year 3 and subsequent years	0.36	0.13	0.23

NOTES:
1. Capital cost includes feed hopper, sizing machine/table, and discharge chutes for direction of fish into containers/bins.
2. The number of workers expected to be required is given in brackets.
3. The number of hours worked per shift is assumed to be 8.
4. The hourly wage rate is assumed to be $8.50.
5. No labour cost is included for opreating a forklift or icing sized fish, since it is assumed that these activities would be required, whether or not raw materials were sized.
6. No data were available for the Grove Telecommunications Limited machine. However, all indications are that its cost structure should be similar to the dual Scangrader.
7. Throughput per shift is assumed to be an average of 120,000 lbs., with sizing being carried out over the full 8 hours.

TABLE 15 - COST OF SIZING WHOLE FISH ASSUMING OPERATION FOR 200 SHIFTS/YEAR

	MACHINE		
	DUAL SCANGRADER	BAADER 486	MANUAL TABLE
1. Capital Cost	$150,000	$75,000	$25,000
2. Annual Costs			
- Amortization of capital cost at 12% per annum, over 10 years	25,526	12,763	4,254
- Maintenance (beginning 3rd year), 2% of Capital Cost	4,500	2,250	750
- Electricity	300	300	300
- Labour for sorting	27,200 (2)	-	40,800 (3)
- Labour for quality inspection	1,700 (1/8)	1,700 (1/8)	3,400 (½)
Totals			
- Years 1 and 2	54,726	14,763	48,754
- Year 3 and subsequent years	59,226	17,013	49,504
3. Unit Cost, ¢/lb.			
- Years 1 and 2	0.23	0.06	0.20
- Year 3 and subsequent years	0.25	0.07	0.21

NOTES:
1. Capital cost includes feed hopper, sizing machine/table, and discharge chutes for direction of fish into containers/bins.
2. The number of workers expected to be required is given in brackets.
3. The number of hours worked per shift is assumed to be 8.
4. The hourly wage rate is assumed to be $8.50.
5. No labour cost is included for opreating a forklift or icing sized fish, since it is assumed that these activities would be required, whether or not raw materials were sized.
6. No data were available for the Grove Telecommunications Limited machine. However, all indications are that its cost structure should be similar to the dual Scangrader.
7. Throughput per shift is assumed to be an average of 120,000 lbs., with sizing being carried out over the full 8 hours.

Manual sizing is less accurate than sizing by machine. Accordingly, to determine which method would be better overall, it is necessary to determine the additional benefit that sizing by machine would likely have, and whether or not the extra benefit more than offsets the additional cost.

Table 12 compares the percentage of whole fish which are consistent in size based on the number of fish in batches of mixed sizes sent through the processing line. (Percentages represent the proportion of the number of fish sorted, rather than the weight).

Even batches of fish which have not been sorted by size are likely to have a large proportion of the fish falling into a single size category. Because the objective of manual sizing is to pick out fish which are different in size from those that make up the bulk of the catch, manual sizing will increase the consistency in size of fish collected in the container at the end of the line. However, inconsistencies in performance by workers result in variable levels of performance, so good average and poor performance levels for manual sizing are shown in Table 12.

Because a machine measures the size of every fish, a greater proportion of the fish in any sorted lot should be consistent in size after a mechanical sorting process. Nevertheless, there will still be some errors, for reasons which were discussed earlier.

From Table 12, it can be observed that manual sorting of flatfish can increase quite considerably the proportions of fish in any lot that are consistent in size. Even when sizing performance is poor, the proportion of fish that are consistent in size can be expected to be at least 25 percent more than that for unsized fish. When performance is good, the

proportion of consistently-sized fish can be expected approximately to double. Improvements in the consistency of sizes of cod can also be quite considerable, although overall accuracy in sorting cod is somewhat less than in sorting flatfish, for both manual and machine sorting.

Based on the results of the experiments, an increase in yield of approximately 1 percent to 1.5 percent can be expected from filleting sized flatfish by machine. From Table 12 it could be further said that

- 36% to 47% of that benefit, or 0.36% to 0.705% improvement in yield, could be realized from manual sizing, when the performance of the workers is poor,
- 56% to 66% of the benefit, or 0.56? to 0.99% improvement in yield, could be obtained from manual sizing, when the workers' performance is average, and/or
- 79% to 86% of the benefit, or 0.79% to 1.29% improvement in yield, could be obtained from good performance in manual sizing.

Although mechanical sorting by size offers a higher overall level of benefits, manual sizing also seems to be a reasonable method, considering its lower cost, provided that good performance can be achieved.

CONCLUSIONS

Based on the results of the work carried out during this project, the following are the principal conclusions which have been drawn. Some caution must be used in interpreting the results of the experiments carried out, because the experiments were out under production conditions, which meant that all of the conditions which could have an impact on the results could not always be controlled and the impact of this problem is difficult to measure.

1. When flatfish are sorted into consistent size categories prior to filleting by a Baader 175 heading and filleting machine, it appears that an improvement in yields can be expected in the range of 1 to 2 percent of input weight.
2. If cod are processed using heading and filleting equipment which are representative of the present state of the art in equipment design, it is reasonable to expect the improvement in yield due to sorting fish by size prior to processing to be considerably less than would be expected from that due to sorting flatfish prior to processing them by machine - however, if older machines are used for processing cod, a higher level of yield improvement is likely to be obtained.
3. Yield benefits from mechanical sizing of fish prior to the hand filleting process appear to be minimal;
4. The modified model 481 Scangrader used during the experiments sorted fish accurately by length but some of the design features of the machine and difficulties with materials handling resulting from these

design features meant that the machine could not give an adequate rate of throughput for sorting in a production environment.

5. The most suitable location for sorting raw materials by size, considering the present practices for purchasing raw materials used by processing companies in Atlantic Canada, is considered to be during discharge of fish from fishing vessels but, to some extent, the final choice of location at each plant is likely to be dependent on the plant's particular situation.
6. Sorting fish into three distinct size categories, while allowing an additional category for fish outside these ranges, seems to be sufficient.
7. Benefits from work simplication in sorting fillets into finished products are likely to be low, when all fillets are cut into portions and/or sorted accurately by weight after an IQF freezing process but some benefits from work simplication might be expected when whole fillets are sorted by size by workers based on visual inspection.
8. Well supervised manual sorting of fish by size using methods which have customarily been used in Newfoundland could provide most of the benefits from sorting fish by size at lower overall cost, so the feasibility of sizing mechanically depends on a comparison of the incremental benefits from mechanical sizing with the additional costs that would be incurred.